Radiative impacts of Arctic sea ice melt

Kristina Pistone

Bay Area Environmental Research Institute

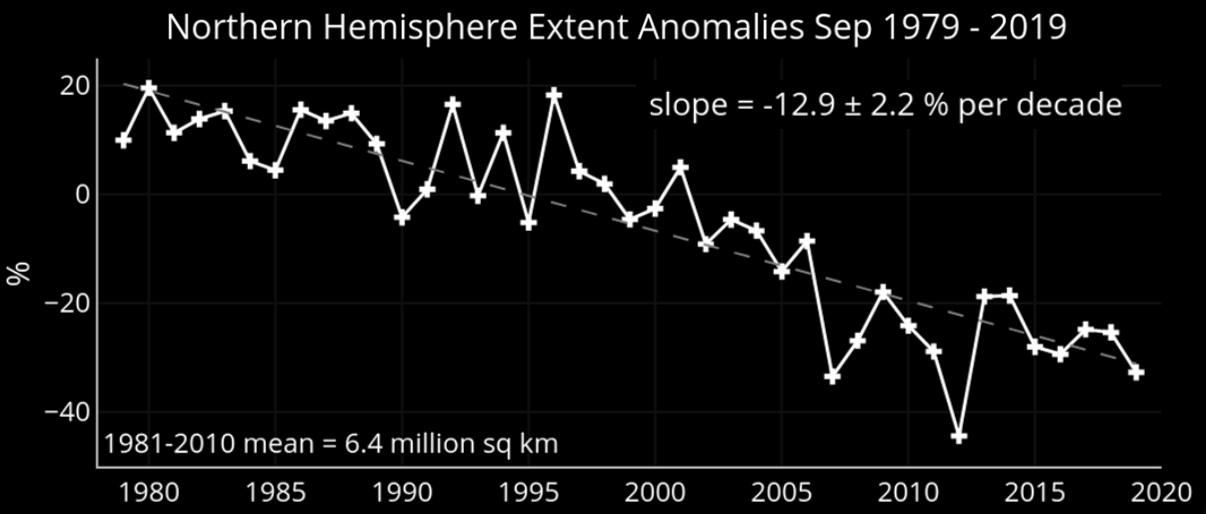
NASA Ames Research Center

with Ian Eisenman, Veerabhadran Ramanathan (SIO)

CERES Science Team Meeting

31 October 2019

The Arctic sea ice is shrinking



- Decreasing sea ice area reduces surface albedo
- Ice albedo feedback
- How much warming has already occurred?
- What happens if the ice completely disappears?

Time series: NSIDC Sea Ice Index;
Globes: visualization by NASA/GSFC Scientific Visualization Studio

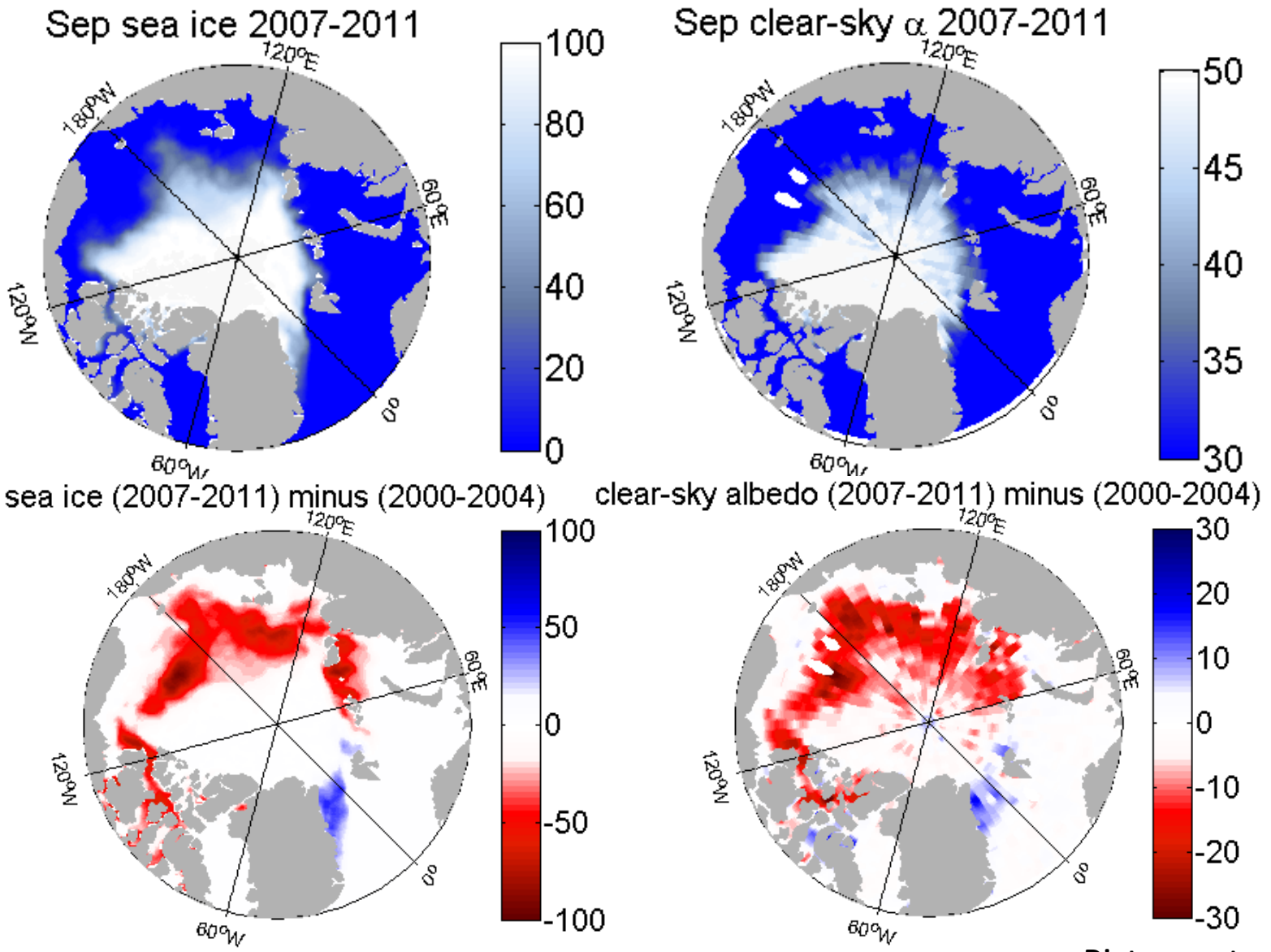
Outline

- Data used
- Radiative properties of the present-day Arctic Ocean
  - **Observed** Arctic sea ice loss and radiative effects
  - Agreement of CERES albedo and microwave sea ice concentration data
  - Updates to Pistone et al., (2014)
- Radiative properties of an ice-free Arctic Ocean
  - **Potential** Arctic sea ice loss and radiative effects
  - Impact of cloud properties
  - Seasonal contributions of heating
- Future work
  - Sea ice-atmosphere processes in observations and models

Data used

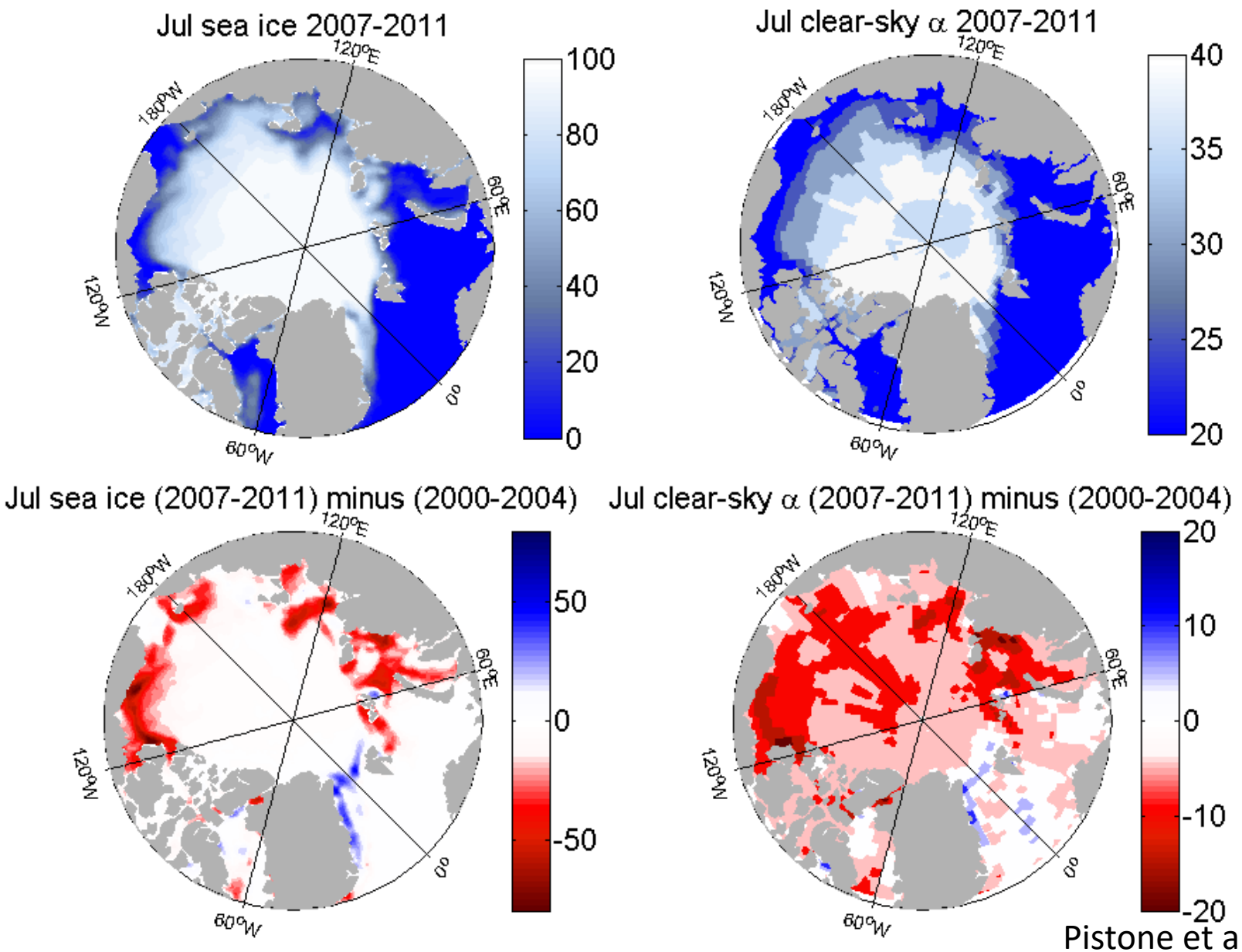
- CERES Terra SSF Ed 2.6 (later updated to Ed 4.0)
- Shortwave radiation (0.3-5µm), 1°x1° resolution data, monthly averages
- COD and f_c from CERES/MODIS
- Sea ice fraction measured from microwave satellites (SSM/I) since 1979 (NSIDC)
- Initial time period of 2000-2011 later extended through 2016

Good agreement between observed ice and albedo trends (fall minimum)



Pistone et al (2014)

July trends show ice albedo decrease



Pistone et al (2014)

Observed albedo and sea ice fraction

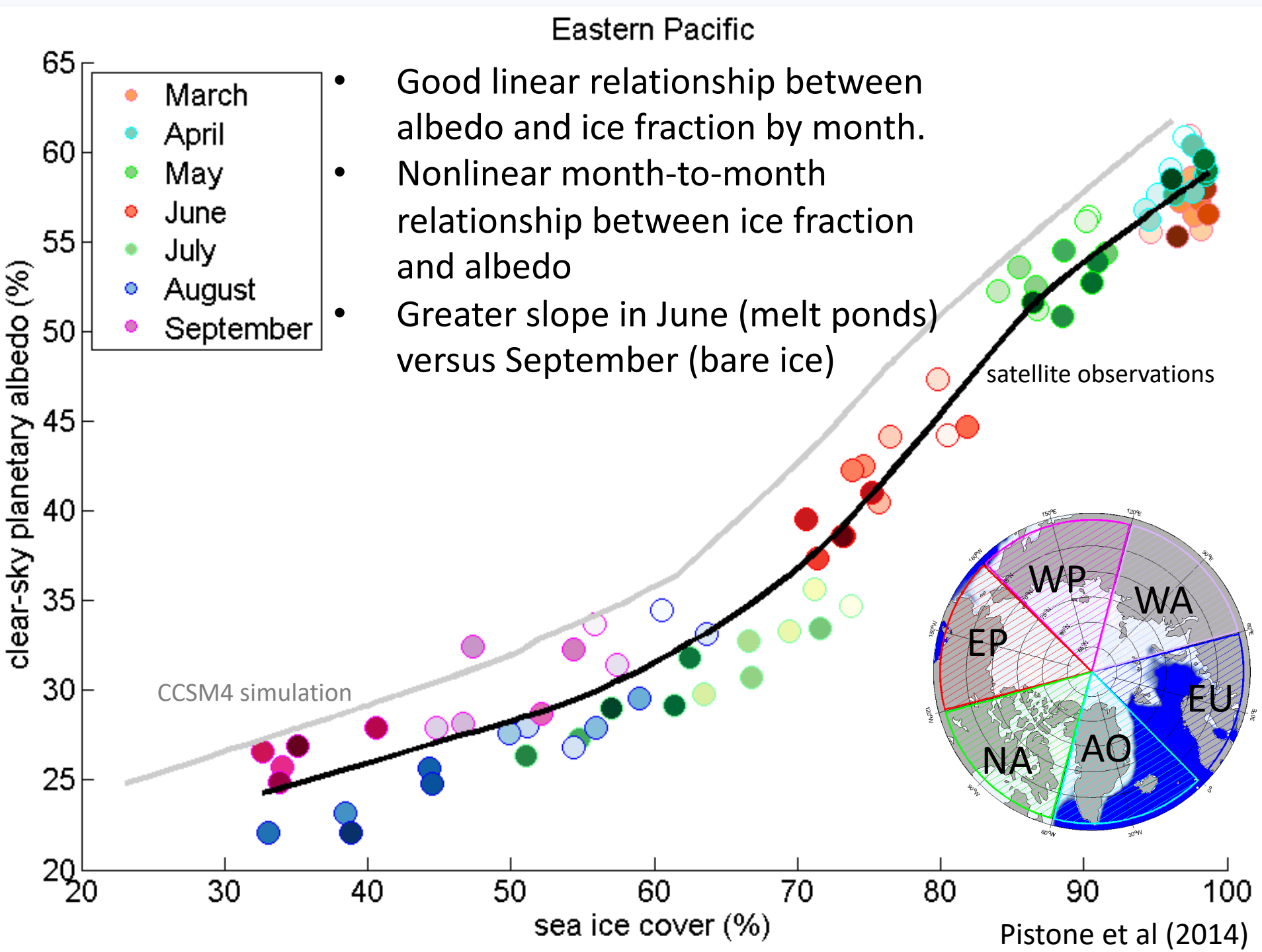
Use this to estimate past albedo from observed past f_{ice}

1979-2011 (Ed 2.6):

- $\alpha_{all\text{-}sky}$ 52%→48%
- 6.4±0.9W/m^2 additional heating, 0.21±0.03 W/m^2 averaged over the globe

1979-2016 (Ed 4.0):

- $\alpha_{all\text{-}sky}$ 51.2%→ 48.0% and 6.2 ± 1 W/m^2

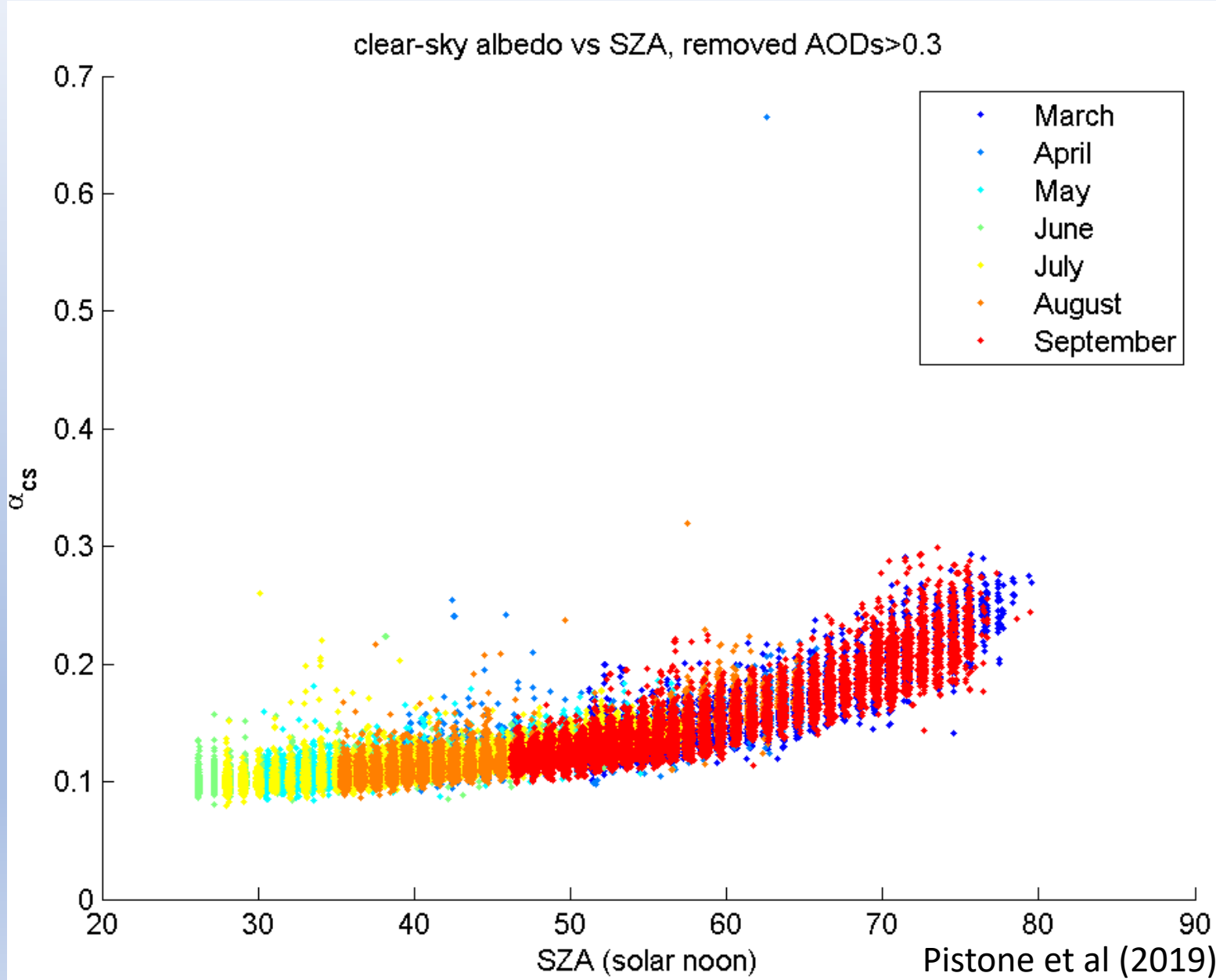


- Good linear relationship between albedo and ice fraction by month.
- Nonlinear month-to-month relationship between ice fraction and albedo
- Greater slope in June (melt ponds) versus September (bare ice)

Pistone et al (2014)

Radiative properties of an ice-free Arctic Ocean

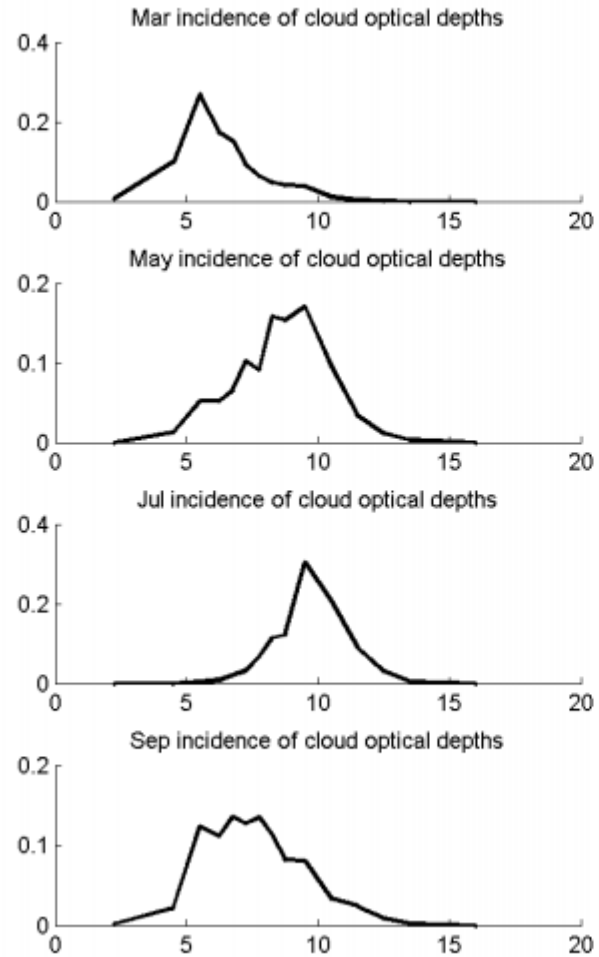
- What does an ice-free ocean look like in latitudes/seasons that have never been ice-free?
- Can we apply a similar framework to extend this relationship to ice-free?
  - (…nope)
- First focus on ice-free, cloud-free data
- SZA/albedo relationship through all seasons

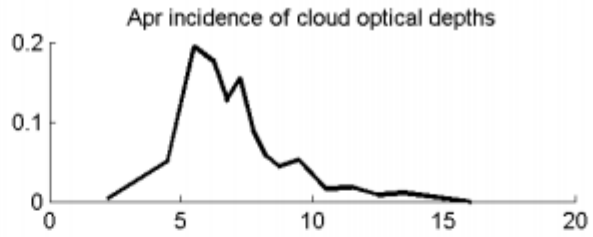


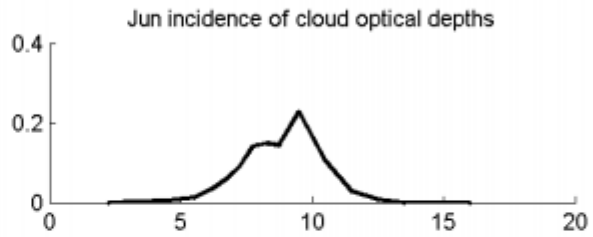
Pistone et al (2019)

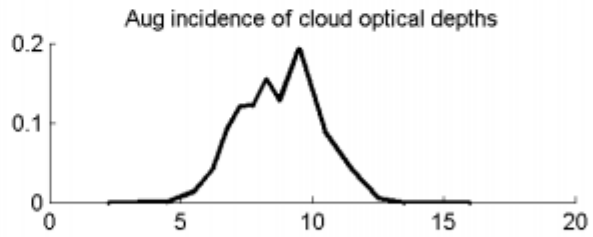
What about clouds?

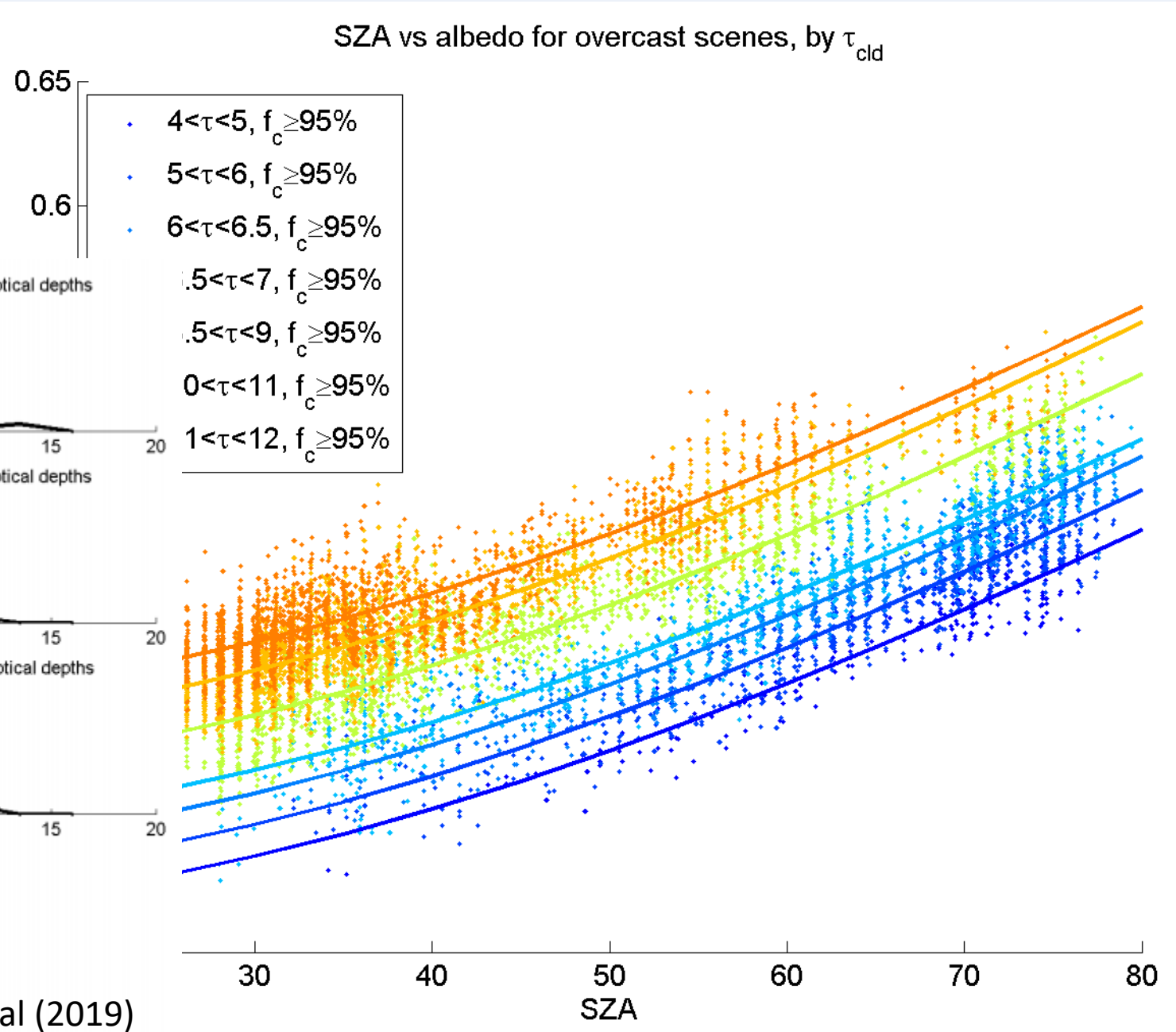
- They complicate the picture…









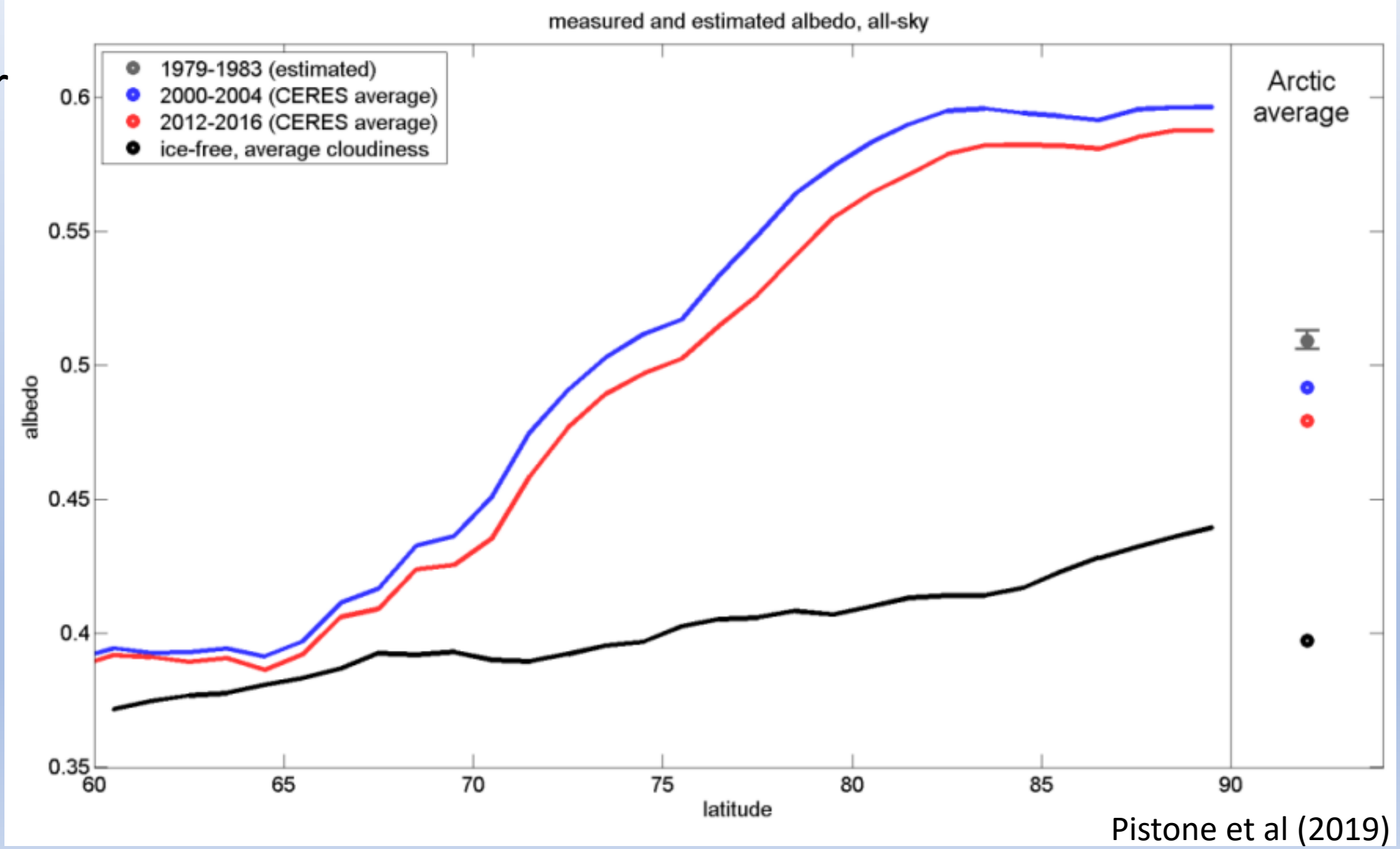


Pistone et al (2019)

Estimated annual-mean all-sky albedo with latitude

- Change in Arctic-average albedo over the CERES period: 49.2→47.9%
- For the first 5 years of the sea ice record: 50.9%
- Ice-free Arctic-average albedo, assuming average cloudiness: 39.7%

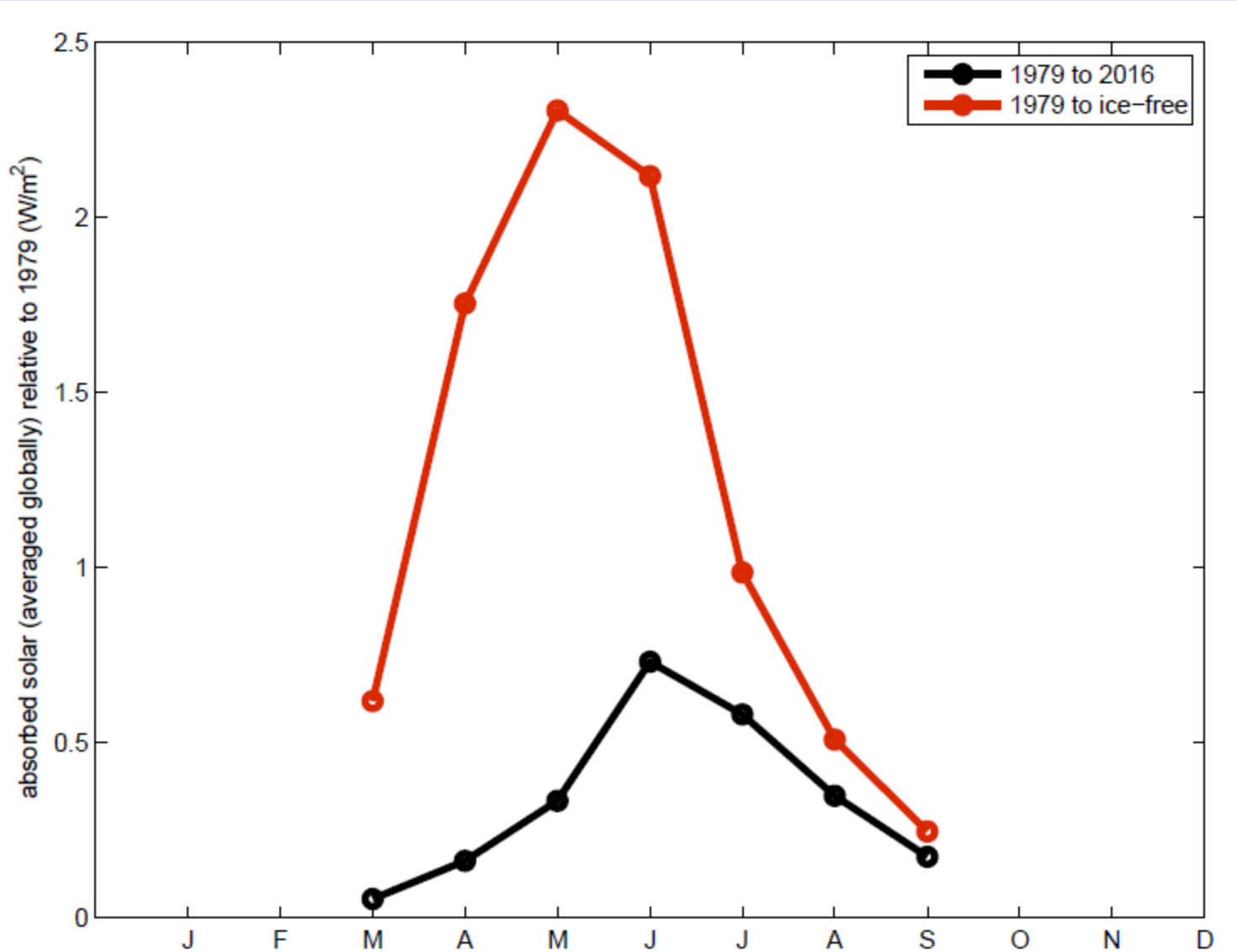
  →21W/m^2 locally, or 0.71W/m^2 globally



Pistone et al (2019)

Seasonal contributions

- Likely forcing is not limited only to ice-free months
- Observed forcing is not even dominated by months of largest ice loss
- Observational record: greatest heating in June
- Potential future period: greatest heating in May (relative to present-day)



Pistone et al (2019)

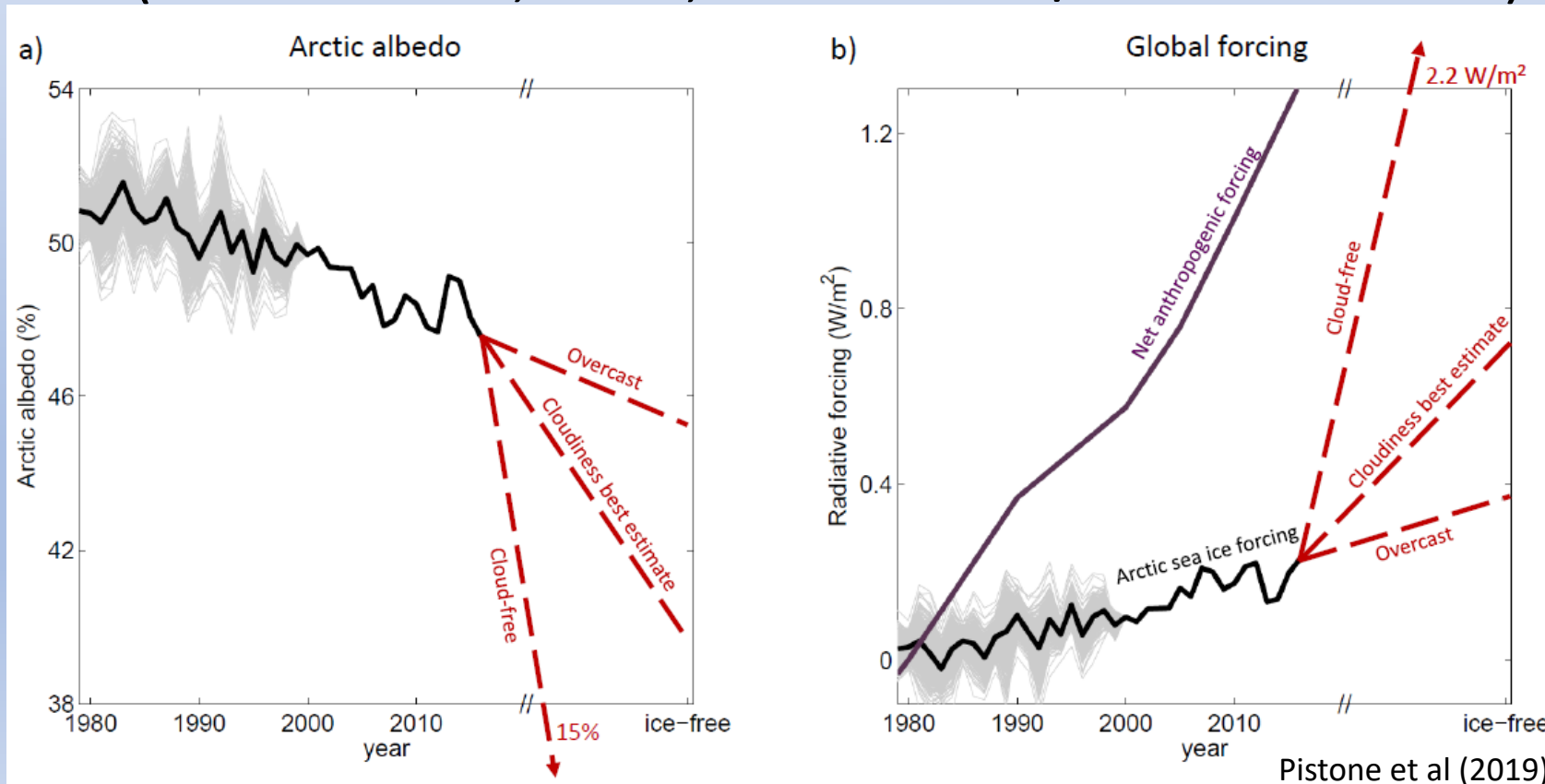
Summary/Future work

- Sea ice/radiative properties show strong relationships in multiple datasets (Pistone et al., 2014, doi:10.1073/pnas.1318201111)
  - (models still sometimes have problems)
- For future ice loss, there is a range of potential radiative impacts largely depending on cloud response (Pistone et al., 2019, doi:10.1029/2019GL082914)
- Future work: to isolate sea ice-atmosphere-cloud processes + the role of ice thickness in observations and models

Thank you!

Questions?

kristina.pistone@nasa.gov



Pistone et al (2019)